

## Helical/spiral CT Scanners

### Sixth Generation (Helical or spiral CT)

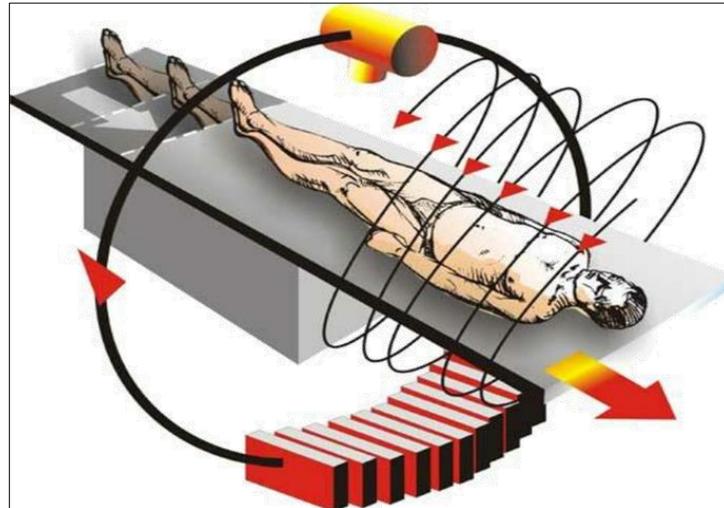
In conventional CT (the *3rd and 4th generation* CT scanners), the patient was scanned *one slice at a time*. The X-ray tube and *detectors rotate for 360 degrees or less to scan one slice* while the *table and patient remain stationary*. This *slice-by-slice* scanning is *time-consuming*. On the other hand, *cables are spooled onto a drum*, released during rotation and re-spooled during reversal. *Scanning, braking and reversal required at least 8-10 sec of which only 1-2 sec were spent for data acquisition*. The result was a poor *temporal resolution and long procedure time*.

Therefore, efforts were made to increase the scanning of larger volumes in less time. This notion led to the development of a technique in which a *volume of tissue is scanned by moving the patient continuously through the gantry of the scanner while the X-ray tube and detectors rotate continuously for several rotations*. As a result, the X-ray *beam traces a path around the patient*.

The development of *helical or spiral CT* was a truly revolutionary advancement in CT scanning that finally allowed true *3D image acquisition within a single breath hold* technique. For more clarification, when the examination begins, the *X-ray tube rotates* continuously while *the couch moves the patient* through the plane of the rotating X-ray beam, (*the table smoothly moves through the rotating gantry*). This means that the X-ray tube and detector perform a '*spiral*' or '*helical*' movement with respect to the patient, generally at a rate of *one revolution per second*.

In this technique the data are *continuously acquired* or collected without pausing while the patient is simultaneously transported at a *constant speed through the gantry*. For this reason the duty cycle of the helical scan is improved to nearly *100% and the volume*

coverage speed performance can be substantially improved. This technique *allows fast and continuous acquisition of the data from a complete volume.*



**Fig. (1): Helical CT**

**Three technological developments were required:**

1. Slip ring technology
2. High power X-ray tubes
3. Interpolation algorithms

**Slip ring technology**

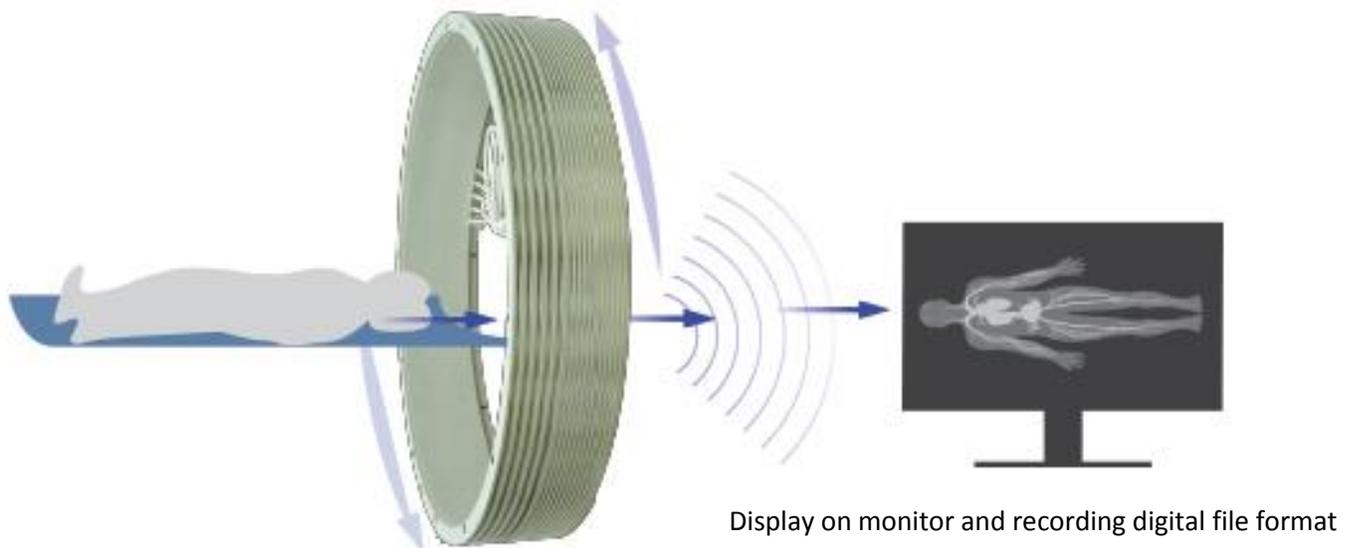
All generations of CT scanners (except 4th gen.) required *winding and unwinding of connection cables causing inter-scan delays.* **Slip ring** was designed to *eliminate this.* A slip ring is *a drum with grooves along which electrical contactor brushes slide.* Data are transmitted from detectors via various *high capacity wireless technologies*, thus allowing *continuous rotation.* Eliminating interscan delays made possible by slip ring technique. *A slip ring passes electrical power to the rotating components without fixed connections.*

It allows the complete elimination of interscan delays except for *the time required to move the table to next slice position.* For eg : if scanning and moving the table each take 1s, only *50% of the time is spent acquiring the data.*

Slip rings are *electromechanical devices* consisting of **circular electrical conductive rings and brushes that transmit electrical energy across a moving interface**. All power and control signals from the stationary parts of the scanner system are *communicated to the rotating frame through the slip ring*.

The slip-ring *design consists of sets of parallel conductive rings* concentric to the gantry axis that *connect to the tube, detectors, and control circuits by sliding contactors* (Fig. 2, 3). These sliding contactors allow the scan frame to rotate continuously with *no need to stop between rotations to rewind system cables*. This engineering advancement resulted initially from a desire to *reduce interscan delay and improve throughput*.

However, *reduced interscan delay increased the thermal demands on the x-ray tube*; hence, tubes *with much higher thermal capacities* were required to *withstand continuous operation over multiple rotations*.



**Fig. (2): Slip ring technology**

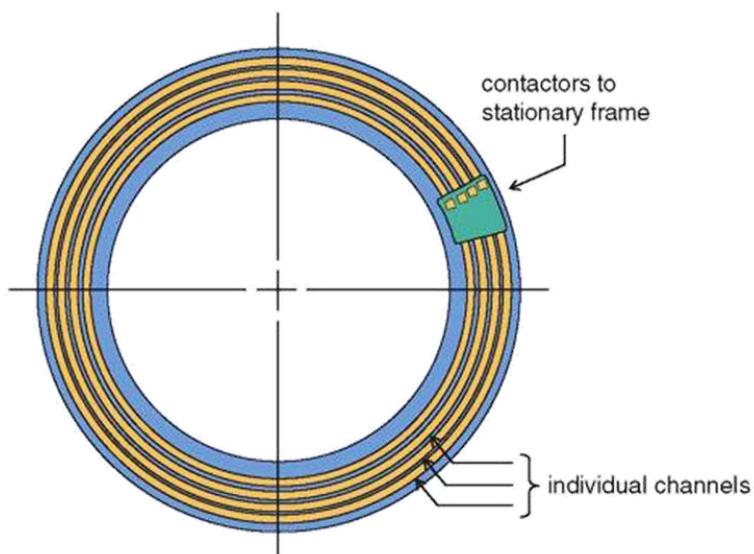


Fig. (3): To convey power onto the rotating gantry from the stationary frame, as well as to conduct signal data from the rotating gantry to the stationary frame, a *slip ring* is used. A slip ring uses gliding contacts to allow communication and power transfer between the stationary and rotating frames *without the use of wires*, and this enables the gantry to *rotate continuously in a single direction*. Slip rings have enabled gantry rotation periods to move from *3.0 s (when cables were used)* to modern CT rotation periods of *as little as 0.25 s*.

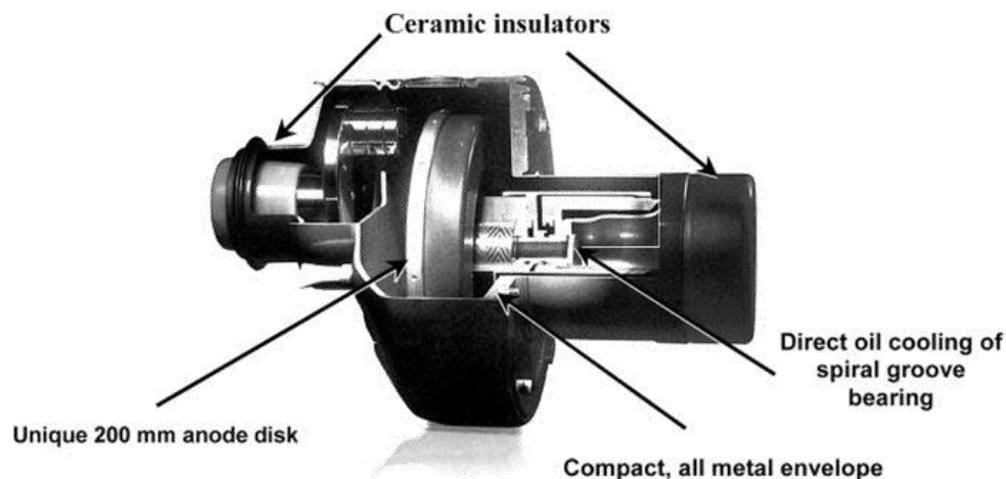
### High power X-ray tubes

X-ray tubes are subjected to far *higher thermal loads in CT than in any other diagnostic X-ray application*. In *early CT* scanners, the power level *was low*. Since *long scan times allowed heat dissipation*. Shorter scan times in *later versions of CT* scanners required high-power X-ray tubes and use of *oil cooled rotating anodes for efficient thermal dissipation*.

The introduction of *helical CT* with continuous scanner rotation *placed new demands on X-ray tubes*. Several technical advances in component design have been made to achieve these power levels and deal with the problems of the *target temperature, heat storage, and heat dissipation*. For example, *the tube envelope, cathode assembly, and anode assemblies including anode rotation and target design have been redesigned*.

As scan *times have decreased*, anode *heat capacities have increased* by as much as a *factor of five*, preventing the need for cooling delays during most clinical procedures, and tubes with capacities of *5–8 million heat units* are available. In addition, improvement in the *heat dissipation rate (kilo–heat units per minute) has increased* the heat storage capacity of modern X-ray tubes.

The *large heat capacities* are achieved with *thick graphite backing of target disks, anode diameters of 200 mm or more, improved high-temperature rotor bearings, and metal housings with ceramic insulators* (Fig. 4).



Among other factors. The *working life* of tubes used to date ranges from *10,000 to 40,000 hours*, compared with the *1,000 hours* typical of conventional CT tubes. Because many of the engineering changes *increased the mass of the tube*, much of the design effort was also dedicated *to reducing the mass to better withstand increasing gantry rotational rates required by ever faster scan times*.

In summary:

*Shorter scan time* required *high power* of X-ray tubes and use of *oil cooled rotating anodes* for efficient thermal dissipation. *Largest heat capacities* are achieved with:

- Thick graphite backing of target disks
- Anode diameters of 200 mm or more
- Metal housing with ceramic insulator.
- The working life of tubes ranges from 10,000 – 40,000